

FORM NO. 51-61A  
NOV 1948

CLASSIFICATION SECRET

CENTRAL INTELLIGENCE AGENCY

REPORT

## INFORMATION REPORT

COUNTRY Germany (Russian Zone)

DATE DISTR. 2 March 1949 25X1

SUBJECT Gas Turbines for Locomotives

NO. OF PAGES

PLACE  
ACQUIREDNO. OF ENCLS.  
(LISTED BELOW)

25X1

DATE OF  
ACQUIREDSUPPLEMENT TO  
REPORT NO.

25X1

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE ACT 50 U. S. C., 31 AND 32, AS AMENDED. ITS TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW. REPRODUCTION OF THIS FORM IS PROHIBITED. HOWEVER, INFORMATION CONTAINED IN BODY OF THE FORM MAY BE UTILIZED AS DEEMED NECESSARY BY THE RECEIVING AGENCY.

THIS IS UNEVALUATED INFORMATION FOR THE RESEARCH  
USE OF TRAINED INTELLIGENCE ANALYSTS 25X1

25X1

a report on gas turbines for locomotives

. is sent to you for retention.

25X1

25X1

MAR 11 3 04 PM '49  
CIA/OSI

CLASSIFICATION

SECRET

| STATE | NAVY | NSRB | DISTRIBUTION |  |  |  |  |  |  |  |  |  |
|-------|------|------|--------------|--|--|--|--|--|--|--|--|--|
| ARMY  | AIR  | ORE  | X            |  |  |  |  |  |  |  |  |  |

25X1

**Page Denied**

**SECRET**

25X1

Performance Characteristics:

25X1

Entire Plant:

## Specific fuel consumption

|                              |                      |
|------------------------------|----------------------|
| at 20° C                     | = about 0.343 kg/HPh |
| at 40° C outside temperature | = " 0.384 kg/HPh     |

Compressor:

|                                            |                     |
|--------------------------------------------|---------------------|
| normal air throughput                      | = about 48.7 kg/sec |
| max air temperature in front of compressor | = 40° C             |
| normal air temp in front of compressor     | = 20° C             |
| min air temp in front of compressor        | = - 40° C           |
| normal air temp behind compressor          | = about 171° C      |
| normal end pressure                        | = 3.59 ata          |
| normal rpm                                 | = 4500 rpm          |

2 Combustion Chambers:

|                                             |                      |
|---------------------------------------------|----------------------|
| normal fuel feed per combustion chamber     | = about 0.215 kg/sec |
| gas temperature at the burner               | = " 2000° C          |
| air for combustion per chamber ca 3.64 kg/s | = " 2.82 cu m/s      |
| air for cooling per chamber ca 20.74 kg/sec | = " 16.05 cu m/s     |

Turbine:

|                                                |            |
|------------------------------------------------|------------|
| under full load, normal input gas temperature  | = 620° C   |
| under full load, normal input gas pressure     | = 3.31 ata |
| counter-pressure                               | = 1.05 ata |
| under full load, normal output gas temperature | = 410° C   |
| normal turbine rpm                             | = 4500 rpm |
| normal generator rpm                           | = 1500 rpm |

Dimensions:

|                                            |                    |
|--------------------------------------------|--------------------|
| combustion chamber height                  | = about 1800 mm    |
| combustion chamber diameter                | = " 500 mm         |
| combustion chamber-turbine connecting line | = 2 X 480 mm       |
| turbine exhaust hoods(2)                   | = 2 X 800 X 750 mm |

**SECRET**

**SECRET**

The controls should include:

- a) Fuel regulation, i.e., regulation of the quantity of fuel relative to the quantity of gas taken in by the compressor.
- b) Temperature regulation, i.e., regulation of the quantity of fuel relative to the temperature of the gas in front of the turbine.
- c) Regulation of output, i.e., control of turbine rpm, and the quantities of air and fuel relative to the motor output required.

The following safety and control devices are also to be provided:

- d) A device which will prevent the gas temperature in front of the turbine from exceeding 650° C under full load and 750° C when starting e.g., an impulse by a thermostat in the connecting line between the combustion chamber and the turbine.
- e) A device that will ignite the air-fuel mixture again if the burner flame goes out, i. e., an auxiliary ignition flame.

The fuel and temperature regulation can be accomplished in the manner originally proposed.

With regard to the rpm and output control, it has been found that the arrangement proposed heretofore is unsatisfactory in that an increase in output is achieved only in the roundabout way of decreasing excitation or vice-versa. Under certain circumstances this can be troublesome, if it is desired to regulate back from maximum load with a compensated shunt regulating resistance.

This arrangement was probably selected, as it has the advantage that in cutting down the output and the turbine rpm, the quantity of fuel and, then, the quantity of air is reduced, so that an inadmissible rise in the temperature of the gas is positively avoided.

Output and rpm control should be so arranged that excitation is immediately increased with an increase in output, and decreased with a decrease in output. This can be done by exchanging the oil line connections on the servomotor, and opposite arrangement of the needle valve and the valve's servomotor.

With this arrangement, a change in rpm will first effect the amount of air advanced, secondly the amount of fuel. The resulting increase in the temperature of the gas in front of the turbine will be regulated to the extent of response of the temperature control. Tests at the combustion chamber should determine the response time of this control.

Provision should be made for easy manual control in event of failure of the automatic control.

Adjustment of the rpm control must be possible from either control compartment. The use of through rotary selectors and long-stroke pull wires is to be avoided.

**SECRET**

**SECRET**

25X1

Economic operation of a gas turbine demands that the turbine rpm be suited to the output required for traction. Based on the turbine shaft, rpm of between 3,000, idling, and 5,000, with maximum load, correspond to turbine output of 0 to 4,000 hp. These are reduced to 900 and 1,500 rpm resp. for the generator by means of the reduction gearing situated between the turbine and the main generator.

Turbine control consists of the following:

- a) Fuel control dependent upon turbine rpm and combustion chamber excess temperature.
- b) Electrical load output control dependent upon turbine rpm.

- a) The quantity of fuel delivered to the turbine is controlled by a two-way valve acted upon by fuel control (8). This valve is in the return line of the burner, i.e., with the valve all the way open only a little fuel comes out of the burners(5) for combustion. Most of the fuel flows back to the fuel tanks. In this case, idling valve (10) cuts down the returning fuel to a point where the turbine is operating at the idling speed of 3,000 rpm.

The fuel control regulating the two-way valve must operate as follows:

1. Regulate valve to increase or decrease fuel to maintain rpm set by engineer.
2. Since there is an optimum output for each rpm rate, each rpm rate set by the engineer requires a certain thermal output, therefore a definite position of the fuel valve.
3. If the maximum permissible combustion chamber temperature is exceeded, the fuel control must reduce the fuel feed accordingly.

**SECRET**

**SECRET**

Note on 1. : The gas turbine rpm counter is to be in the form of an oil pressure circuit, consisting of a metering oil pump (16), powered directly from the turbine shaft, a choke valve (17a) adjusted by the controller, and a pipeline connecting the two parts. The oil pressure in the pipeline depends on the pump (16) rpm and the aperture of the running valve (17). The relation of oil pump feed to the throttling action of the running valve is so arranged that the pressure occurring is the same at all prescribed rpm counts; i.e., despite an increase in pump output at higher rpm the oil pressure remains the same since the running valve is opened in accordance with the increased pump output. If the rpm count falls below or exceeds the running valve setting the oil pressure in the pipeline falls or rises accordingly. This oil pressure is transmitted to a jet pipe regulator by means of a pressure difference measuring gauge. This regulator operates the fuel valve servomotor so that fuel is reduced with increasing rpm, increased with decreasing rpm.

Note on 2. : So that each rpm rate set by the engineer will be associated with a definite fuel quantity, a second adjustment valve (17b) is included on the controller. This valve so regulates a secondary oil pressure circuit, a branch of the control oil pressure circuit leading to the above-mentioned pressure difference gauge of the fuel control, that with increasing rpm the ~~pressure corresponding to~~ gauge receives increasing pressure. The gauge thus receives oil pressure corresponding to actual turbine rpm, and oil pressure corresponding to the rpm as set. The gauge's action on the jet pipe is thus dependent upon the turbine rpm and the running valve adjustment. A control spring on the jet pipe balances the action of the gauge. The action of this spring depends upon the adjustment of the servomotor operating the fuel valve. In order to coordinate the predetermined optimum fuel quantity with each turbine rpm rate, the cam on the control

**SECRET**

**SECRET**

(8), which determines the action of the control spring, is adjustable.

Note on 3. : In order to avoid exceeding the maximum permissible temperature, a thermometrical device is used to act on the fuel control. It consists of a measuring gauge (12) and a pneumatic measuring circuit which operates similarly to the Wheatstone bridge electrical circuit, measuring the air delivered through the jets into the combustion chamber. The pressure gauge (12) acts on fuel control (8) when the maximum permissible temperature is exceeded, cutting down fuel delivery to the combustion chambers.

b) Electrical charge Output Control Dependent upon Turbine rpm.

Control of the electrical charge, which corresponds to tractive power, is dependent upon turbine rpm. The turbine rpm count for this purpose comes from the same oil pressure circuit used for fuel control. The pressure between the pump (16) and the running valve (17a), with the help of a measuring gauge and jet pipe control (18a), is used to adjust the servomotor (18b) which, in turn, operates the field rheostats for the exciters (15) of both the main generators (13) and the propulsion motors. The field rheostat must be able to regulate through the entire control field at all turbine rpm counts.

Regulation of the turbine and the electrical output for tractive power is as follows:

Starting: When the running valves (17) are opened, the oil pressure at the fuel control (8) and field rheostat (18a) measuring gauges drops, and the counter pressure at measuring gauge (8) rises. The fuel control jet pipe moves to the right and the fuel valve in the return line behind the burners (5) is closed, so that the burners then receive the full-load fuel quantity. The rising temperature in the combustion chambers results--via the thermometrical device--in regulation of the fuel feed to the temperature-indicated amount. The turbine rpm is increased due to the greater quantity of fuel. Simultaneously with the fuel regulation, the jet pipe for the field rheostat, affected by measuring gauge (18a), is

**SECRET**

**SECRET**

moved right and the servomotor (18b) is shifted to its end position left. With the servomotor in this position, the right field rheostat has weakened the excitation of the main generators as much as possible, the left field rheostat has increased the propulsion motors' excitation to maximum through excitation of the exciters. When turbine rpm reaches and exceeds the running valve setting, the increased output of the pump (16) raises the pressure at the measuring gauges to a point where the jet pipes move left, the fuel feed is reduced, and the field rheostat so adjusted that the main generator voltage rises to 720 v, following which the propulsion motor fields are weakened so that finally, a running speed of 100 km per hr is attained.

Tractive power is increased by further opening the running valves, and the process described for starting is repeated. Due to resultant electrical discharge, with simultaneous increase of fuel feed, turbine rpm is rapidly increased; when it has reached or exceeded the setting, the jet pipes move left reduce fuel feed to the new setting and increase generator excitation as long as the turbine shows a tendency to exceed the new rpm setting.

Tractive power is reduced by partly closing the running valves (17).

For braking, the controller handle is reversed. This adjusts running valve (17a), and a new rpm setting is affected in the turbine oil pressure measuring circuit. Since, during electrical braking, the turbine receives only the fuel quantity relative to the 3,000 rpm idling speed, the control magnet (11) at the fuel control is excited, the jet pipe is adjusted so that only the fuel quantity for idling reaches the burners. In order to maintain the new turbine rpm setting the propulsion motors are now operated as generators and the main generators operate as motors, drive the turbine and run it up to over 3,000 rpm. The power thus introduced to the turbine is taken up by the compressor and partly exhausted into the air through brake valve (23). The compressor

**SECRET**



**SECRET**

valve (23) is held shut during running operation by the spring and the piston pressure. In braking it is held only by the spring, which is so arranged that <sup>when</sup> the compressor speed exceeds 3,000-rpm and the pressure rises, the valve opens and the proper amount of compressor air is released. Main generator and propulsion motor regulation is accomplished through the measuring gauge, and the jet pipe controls (18a) the servomotor (18b) and the field rheostats (18). However since initial braking control must occur from the field rheostat end position opposite that used when running, proper adjustment of the rheostat is brought about at start of braking through excitation of the control magnet (20) on the jet pipe regulator. After switching in the motor cutout relays by way of a contact in this end position of the field rheostat, the magnet (20) is again disconnected, and the oil pressure circuit can resume control of the field rheostat.

Idling at 4,000 rpm: For short station stops, the engineer may set the turbine idling speed at 4,000 rpm in order to have increased power for starting. By way of a switch in the cab the control magnets <sup>on the fuel control, and control magnet (19)</sup> (9) on the field rheostat may be cut in. While the field rheostats <sup>^</sup> thus remain in the starting position for running until actual starting despite increased pressure in the oil circuit, the balance between control spring and the pressure of the pressure difference measuring gauge (8) is so altered that the turbine receives the required amount of fuel.

Motor cutout: A motor cutout adjustment valve (21) is provided in order to prevent overloading propulsion motors remaining in operation when one or more develop trouble and are shut off. This valve, situated in the counter pressure oil circuit of measuring gauge (8), is closed according to an established scale as one or more motors are shut off, changing the relationship between fuel valve adjustment and turbine rpm.

**SECRET**

**SECRET**

Then the gas turbine can still be operated, with suitable electrical discharge, at maximum rpm; but as a result of reduced fuel feed, the power proportionate to this rpm is no longer available.

Temperature adjustment: The efficiency of the gas turbine depends much upon the outside temperature. The possibility of varying the rigid-fuel-rpm ratio is therefore desirable. The fuel may be regulated according to the outside temperature by means of a manually adjusted cam plate (30) which affects the fuel control similarly to the 4,000 rpm idling adjustment.

**SECRET**

**SECRET**

25X1

The basis of the arrangement is a controller, operated by the engineer, which simultaneously adjusts the turbine rpm control and the fuel valve. Combustion chamber temperature control is also provided at the same time. The entire power output range is to be covered in 15 stages, zero to full load.

Motive power is regulated by varying the rpm rate of the turbo set. The rpm rate is regulated from the load side by varying the load moment with the help of the shunt regulating resistance of the generator. Increasing the rpm setting reduces a load moment and the turbine accelerates accordingly. As the setting is approached, the load is increased to a point where a state of equilibrium sets in and the rpm rate is maintained as set. For supporting acceleration, the combustion chamber temperature is temporarily increased through the stage selector. If the motive power is reduced, the control increases the load moment, the turbine is braked and the process is reversed. Some of the accelerating force for the turbo set in case of a power increase is thus covered by the energy of the moving train, and it is assumed that during the control process the speed of the train is not noticeably changed.

**SECRET**

**SECRET**

From our calculations, we perceive that about 1 percent of the train energy would be needed to accelerate the turbine from zero to operating rpm. Since the train energy varies with the square of the velocity, the train speed would reduce about  $\frac{1}{2}$  percent if, during acceleration of the turbine, the tractive power were reduced to zero and the entire effective power were used for accelerating the turbine. This value is for the extreme case. Generally, turbine power amounts to less than .001 of the train energy. It is thus evident that acceleration power as compared to train energy is of little note. For this reason an increase of motive power by raising the temperature can be eliminated. In this case stage control is no longer necessary and power variation can be a continuous process. It thus appears more practical to regulate fuel and rpm relative to each other and not parallel. Since the combustion chamber temperature depends primarily on the oil/air ratio it is advisable to use the air quantity instead of the rpm rate as the basic quantity.

#### B. Description of the Control System

The best solution is contained in the attached drawing, key to which is as follows:

- 1 - Compressor
- 2 - Combustion chambers
- 3 - Turbine
- 4 - Heat exchanger
- 5 - Oil burner
- 6 - Oil pump
- 7 - Oil flow control valve
- 8 - Main generator
- 9 - Shunt regulating resistance (controlling main generator output)

The control system consists of:

- 10 - Fuel control
- 11 - Temperature control
- 12 - rpm control

**SECRET**

**SECRET**

Fuel control: Each quantity of air to the combustion chamber is coordinated with a definite quantity of fuel. The air quantity is measured at the compressor intake connections by taking the negative pressure there. According to your information, this is about 600 mm (water column) at full load. Filter resistance and relative wind have no effect; only the difference in pressure between the filter and the compressor inlet is measured. This pressure is applied to control diaphragm (13) which activates an oil-fed jet pipe (14). Adjustment of the jet pipe operates the servomotor (15) which adjusts the fuel valve and simultaneously moves a cam plate (16). A roller runs on the cam plate and affects the tension of the spring (17). When the jet pipe is in a state of equilibrium, the pressure of the <sup>diaphragm</sup> ~~diaphragm~~ and spring is balanced and the adjustment of the motor is then determined by the shape of the cam. The cam consists mainly of a steel band whose profile can be changed by means of a series of screws. It is thus possible to coordinate a fuel valve opening with <sup>any pressure</sup> ~~any pressure~~ on the diaphragm, thus a definite fuel quantity with every air quantity. The development of this control and the cam form depend upon the burner used. A Peabody-type is assumed for the diagram.

The relation between ■ diaphragm pressure and spring tension can be adjusted through the slide valve (18) from the lever (19). The lever is adjusted by hand according to the outside temperature.

Temperature control: Due to the air-fuel regulation the combustion temperature is already approximately established. It is accurately maintained by a temperature control which responds to the critical temperature of the gas flowing into the turbine. The best method appears to be an air thermometer, operating as follows:

A small, fireproof tube stretches through the measuring chamber (location to be decided) with a measuring choke inserted at the

**SECRET**

~~SECRET~~

hottest point. Through this choke is forced a certain quantity of air taken from the compressor and kept constant through a small pressure regulator. After flowing through, the air is released. The flow pressure at the hot choke is proportional to the absolute temperature, and is applied as a measure for that temperature to the control diaphragm (20) of the temperature control. The movement of the measuring gauge adjusts a small valve (21) which releases secondary air into the lead to diaphragm (13). An increase in combustion temperature causes the supplementary air intake to open, thereby lowering the value for the air quantity, and the control adjusts to a smaller oil quantity lowering the combustion temperature accordingly. A reduction in temperature causes the opposite effect. Parallel to the measuring choke's air current, a second current is produced causing a back up of pressure at an auxiliary choke. However, this auxiliary choke is not heated and is so adjusted that at the desired temperature the same pressure increase occurs as at the hot measuring choke. This pressure affects the second side of control diaphragm (20) and keeps the measuring choke pressure in balance when the temperature is normal. The entire system is the pneumatic counterpart of a Wheatstone bridge and provides a sensitivity of measurement in which, like the latter, small anticipatory variations have no effect. The auxiliary choke throughput can be altered by means of a moveable cone, which will adjust the temperature setting. By operating the adjustment lever for the outside temperature, this cone is adjusted by means of a cam plate to the desired temperature decrease. A second choke is situated parallel to the auxiliary choke; its cone is moved relative to the position of the controller. At low rpm, this choke is gradually closed and the temperature is lowered.

Control of rpm: In the system planned, turbine rpm rate is controlled from the load side by varying generator excitation through shunt regulating resistance (9). It appears practical to control the generator through a current-regulating exciter in order to induce a small time

~~SECRET~~

~~SECRET~~

constant. For measuring rpm, there is a small gear pump coupled to the generator. This pump sends a quantity of oil corresponding to its rpm across measuring choke (24). The pressure gradient produced at the choke acts through measuring gauge (25) of the rpm control (12). With a given pressure adjustment on the control the pump rpm is proportional to the opening of measuring choke (24), and adjustment of this choke will adjust the rpm. Handwheel (26) is used for operating the system. Oil for the pump is taken from the tank containing the oil supply for the fuel and rpm control. The motion of pressure gauge (25) moves a jet pipe (27) which activates servomotor (28). This operates the generator excitation control. The control process is stabilized by follow-up cylinder (29).

Control stability: Basic figures for calculating stability conditions are as follows:

Moment of inertia = 10.2  
Power = 3,000 hp = 225,000 mkg/s  
rpm = 6,000  
Angular velocity = 630 /s  
Turning moment = 356 mkg  
Angular acceleration = 36 /sec<sup>2</sup>  
Inertia constant = 18 sec  
Generator time constant = 0.7 sec  
Servomotor contact time = 0.05 sec  
Irregularity (coupling factor) = 0.15  
Damping = 0.74

Our calculations show that sufficient stability may be attained if contact time (adjustment period of servomotor) and control coupling are suitable.

~~SECRET~~

**SECRET**

Operation: To increase rpm rate and locomotive power, the engineer turns the handwheel to open choke (24). The pressure in gauge (25) drops immediately, the jet pipe moves right. The servomotor (28) then moves the shunt regulating resistance to reduce generator excitation. The load moment is then reduced and the turbine accelerates until, through the increased rpm and consequent increased output of pump (23), the proper pressure is attained at the measuring choke. As this pressure is approached, the control increases excitation and, thus, the charge until a state of balance is reached and the set rpm rate is attained. In reducing turbine power (rpm), the process is reversed. If, by continuous reduction of power, an rpm rate slightly above idling speed is reached, further closing of choke (24) opens a valve (30), and the pressure at the fuel control is dropped to almost zero. The fuel control, independent of rpm and air quantity, then shuts off the fuel feed, and idling valve (31) maintains a fuel flow in accordance with turbine idling speed. Since the rpm rate is now less than the relative setting of choke (24), the rpm control, attempting to reduce the load still further, switches the shunt regulating resistance to its switch-off position. The plant then continues to run at idling speed. The rpm rate at which fuel feed is switched to idling rate must be so chosen that the temperature increase during power pickup does not exceed the permissible as a result of the sudden increase in fuel feed.

Thus, normal running requires nothing more than operation of handwheel (26), except for braking which is accomplished independently of running control, by opening valve (32). Fuel control adjustment to outside temperature is necessary only seasonally, or perhaps, in some cases, for day operation and night operation. Safety devices might include a fuel cut-off effective at rpm and temperature limits, and at dangerous generator overload through an overload relay.

**SECRET**



**SECRET**

25X1

The spatial arrangement of the controls depends entirely upon the structural arrangement of the locomotive. If space is sufficient, the fuel control with the temperature control and also the rpm control might be built into a case to be mounted in the turbine or generator compartment. If space is limited, the controls may be mounted directly on the machines. Dual adjustment of rpm control is easiest and simplest with a rotary selector or a long-stroke wire line as used for airplane controls. Fuel adjustment (occasional, for outside temperature) from the cab will probably be unnecessary. There should be provision in the cab for mechanical adjustment of the fuel valve in the event that the fuel or temperature control fails; and a similar adjustment should be provided for the shunt regulating resistance of the generator in event the rpm control fails. The equipment for starting the turbine is not touched by the control system.

Instruments: Cab instruments are held to a minimum. The following are recommended for each cab:

- 1 speedometer
- 1 ammeter, calibrated in tons tractive power
- 1 scale, on controller handwheel, with calibration in turbine rpm or also in hp

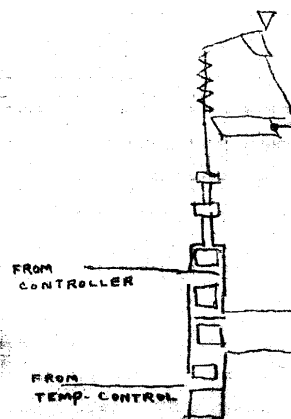
It would also be advisable to have:

- 1 temperature gauge for combustion chambers
- 1 follow-up instrument for the measuring pressure and control pressure of the quantity of air for combustion, which gives a reference for the intervention of the temperature control

If readings on the two indicators correspond, the temperature control does not intervene. If the control pressure indicator lags the oil quantity for the temperature control is increased. If the indicator advances, the oil is reduced. The return cam on the fuel control should be so adjusted that when a state of balance is attained the temperature control intervenes but little, the two indicators remaining nearly in agreement. The temperature gauge and follow-up device could be situated in the machine compartment as are the pressure and rpm counters for the turbine.

Approved For Release 2008/10/03 : CIA-RDP83-00415R001100040006-8

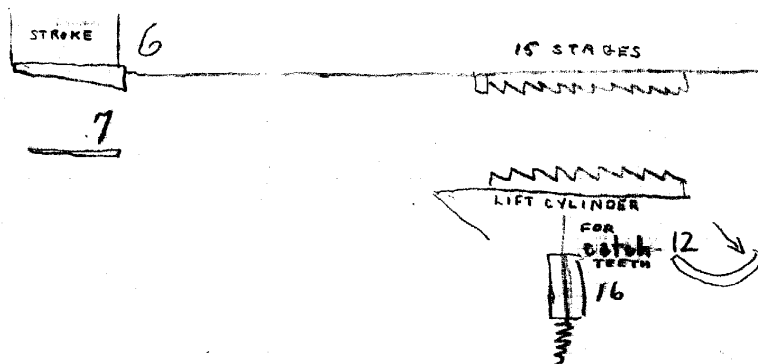
**SECRET**



**SECRET**

Approved For Release 2008/10/03 : CIA-RDP83-00415R001100040006-8

**SECRET**



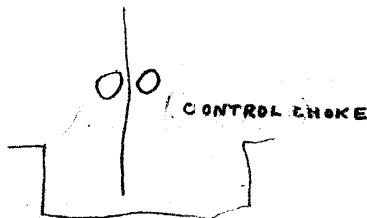
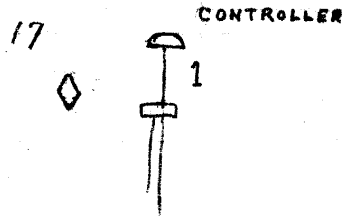
 FUEL

 LOW PRESSURE  
RPM REGULATOR

**SECRET**

**SECRET**

LOCKING DEVICE



CONTROL CHOKE

LOW PRESSURE



RPM REGULATOR

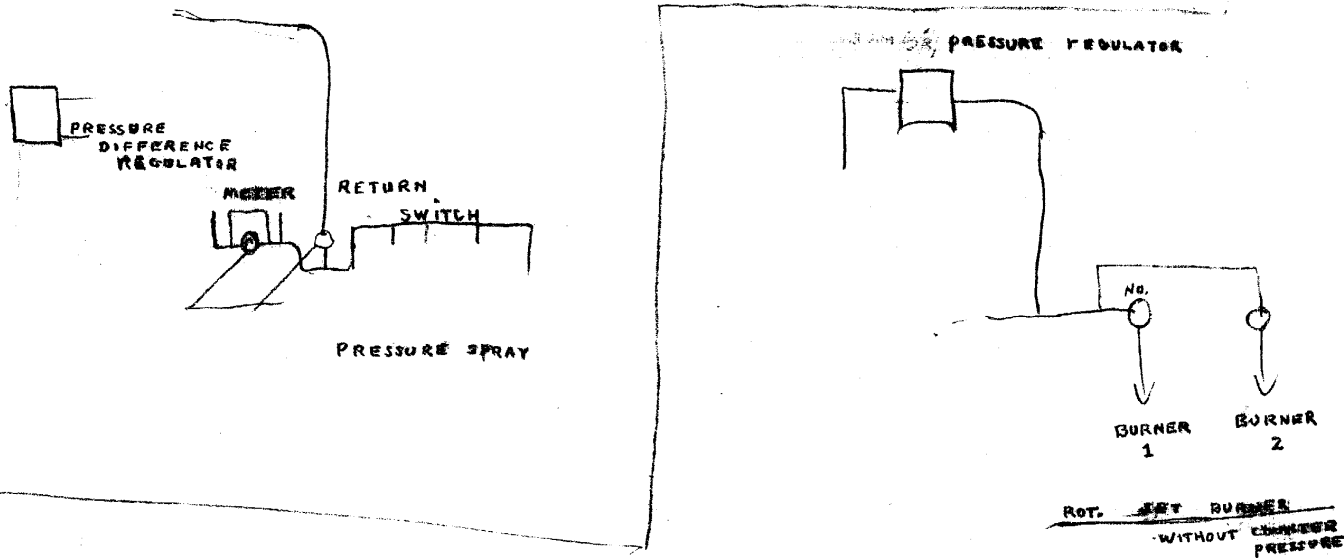
**SECRET**

B'

**SECRET**

FUEL OIL HOOK-UP FOR RETURN BURNER

MIN 150 kg/hr



**SECRET**